GEOTECHNICAL BASE STUDY FROM COREHOLES OF THE SAND WASH PROJECT SITE

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2.0 SUMMARY AND CONCLUSIONS

2.1 REGIONAL GEOLOGY

The Sand Wash property is located in the south flank of the Uinta Basin - a Rocky Mountain type structure. Structural deformation of the basin occurred from the Cretaceous to early Tertiary time, 135 to 35 million years ago. The south flank dips generally north and is structurally uncomplicated with a few low-relief plunging folds and a few minor faults. Northwest trending gilsonite veins occur in the area with the largest veins being 10 miles long and 18 feet wide.

2.2 LOCAL SURFACE GEOLOGY

Surface rocks are the Uinta Formation sandstones, siltstones, and shales. Jointing occurs predominantly in the sandstones. A photogeologic study identified joints striking mostly in two directions - N 60° to 80° W and 10° to 40° E. No evidence of faults was observed in the shaft site area. The average strike of the bedrock is N 75° E, and the dip varies between 1 and 5 degrees.

Flat-topped mesas of hard sandstone separated by broad valleys of less resistant siltstone and shale are characteristic of the area's topography. Relief is mostly 50 to 100 feet. Drainage channels are normally dry but carry large flows during snow melt and after storms

2.3 LOCAL SUBSURFACE GEOLOGY FROM SHAFT PILOT HOLE = 13X-2 ? (p.13)

Major stratigraphic units obtained from the corehole are as follows:

Unit	Depth (ft)	Description of Rock Types
Uinta Formation	Surface to 1000	Predominantly siltstone and sandstone with minor amounts of shale and marlstone
Transition	1000 to 1348	Marlstones and oil shales become major constituents interbedded with sandstones and some siltstones similar with those above
Green River Formation	1348 to 2193 (core TD)	Oil shale and marlstone with minor tuff beds and disseminated saline minerals

High grade oil shale occurs between the "A" and "B" grooves of the Mahogany Zone, (Green River Formation), at depths of 2077 and 2180 feet, respectively. A 33-ft thick mine zone has been defined between 2117 and 2150 feet.

Sedimentary bedding was essentially flat with dips of 0.5 to 1.5 degrees being measured northwesterly. A few dips of 10 to 15 degrees were measured along short intervals probably reflecting post-depositional slumping or cross-bedding.

Geologic discontinuities were classified as partings if they occurred parallel to the sedimentary bedding, or as joints if they crossed the bedding at an angle. Location of all partings and joints is shown in the geologic log in the Appendix.

Spacing of partings varied from less than one inch to several tens of feet.

Only 65 joints were logged in the entire cored interval. The following dips were measured:

No. of Joints	Percentage	Dip
41	63	Vertical or nearly vertical
18	28	55° to 80° from horizontal
6	9	25° to 50° from horizontal

Over half of the joints were sealed or recemented. Very few joints or partings contained mineral coatings or showed evidence of weathering. When present, the most common infilling material was "asphaltic" crude oil in open discontinuities.

2.4 EVALUATION OF ROCK QUALITY

Good rock quality was indicated by the high core recovery, excellent RQD (Rock Quality Designation) index, and laboratory physical property tests.

Core recovery amounted to 95% with most of the core losses being due to mechanical problems.

RQD was mostly classified as excellent as indicated in the following table:

RQD	Length (ft)	Percentage
Excellent	1739	86
Good	145	7
Fair	120	6
Poor	10	1/2
Very Poor	10	1/2

Rock above the mining zone had medium to high strengths with unconfined strength values ranging between 11,500 and 22,000 psi. The Mahogany Zone rock was classed as medium strength with values ranging mostly between 6,000 and 11,000 psi, although a bed of high strength rock indicated by a value of 28,000 psi was found in the roof area. Relatively high shear strength parameters - cohesion and friction angles - indicative of competent rocks were obtained from triaxial tests.

The above results indicate that good rock quality should be expected during sinking operations. Unless water is a problem no stability problems are anticipated and structural lining seems unecessary.

2.5 HYDROLOGY

Two aquifers occur in the Green River Formation - the Upper Bird's nest aquifer zone between the depths of 1524 and 1574 feet, and the Lower Bird's-nest between depths of 1625 and 1800 feet.

Two water producing horizons were found in the first aquifer respectively between the depth intervals of 1529 to 1534 feet, and 1565 to 1574 feet. Core observations indicated that the first horizon comprised a zone of interconnected, leached-out nacholite cavities.

The second horizon was formed essentially by vertical fractures. Measured flow into the drill hole varied from 300 gpm at the top of the aquifer to 570 gpm at the bottom.

Conversion to aerated circulation prevented measurements of water flow in the Lower Bird's-nest aquifer, but no pressure surges indicative of flow were noticed. Inspection of the core, however, showed leached nacholite cavities at 1625 feet and between 1768 and 1775 feet suggesting the presence of water-bearing horizons.

A low volume sandstone aquifer was encountered in a drill hole two and a half miles north of the shaft pilot hole in the interval above 1525 feet, in the Uinta Formation. Flows have been reported also from this formation in the general area. It appears that water occurs in randomly distributed lenticular channels. The absence of water in the Uinta Formation in the shaft pilot hole does not ensure against its occurrance within short lateral distances.

2.6 HYDROCARBONS

Hydrocarbon gases were monitored by a hot-wire gas detector and chromatograph. Methane readings were recorded at depths of 520 feet, and continuously in the interval of 916 to 970 feet. High gas readings were measured below 1208 feet and continuously from 1550 feet to total depth. No large gas flows were observed during drilling. It is possible that the gas is originating from a few low volume, low permeability horizons.

Liquid and solid hydrocarbons consisted of gilsonite and "asphaltic" (in appearance) crude oil. This material was present in almost every porous zone below 760 feet.

3.0 GEOLOGY

3.1 REGIONAL GEOLOGY

The Uinta basin of northeastern Utah includes an area of more than 9300 square miles. It is a typical Rocky Mountain type, asymetric, Tertiary structural basin. Its extent is outlined by outcrops of Cretaceous and older rocks on the north and by the Roan cliffs on the south. The synclinal axis trends northwesterly in the eastern part of the basin, passing about 10 miles south of Vernal. The older formations north of the axis dip steeply southward, with the younger, tertiary units pinching out or truncating against them. South of the axis the dips of all formations are irregularly northward, and are mostly between one and five degrees.

Structural deformation of the basin began after deposition of the Cretaceous Mesa Verde Formation and continued through early Tertiary time. During this period the basin was filled with continental sediments of the Wasatch, Green River, Uinta, and Duchesne River formations. These sediments range from fluvial-shoreline-deltaic, coarser sands and shales of the Wasatch, Uinta, and Duchesne River to mostly very fine-grained, lacustrine, organic marlstones of the Green River Formation. The gently dipping south flank of the basin is structurally uncomplicated, at least in the younger beds. There are a few low-relief, northward- and westward-

plunging folds and a few minor faults of small displacement. The most prominent features are the large number of northwest-trending gilsonite veins, many of which extend for ten miles or more and achieve widths of as much as 18 feet although most are less than 5 feet wide.

3.2 LOCAL SURFACE GEOLOGY, TOPOGRAPHY, AND CLIMATE

The Sand Wash unit is on the gently northward dipping south flank of the Uinta basin, about 22 miles south of the syncline axis. Figure 4 shows Tosco's leases and the approximate location of the proposed shaft. Rocks at the surface are sandstone, siltstone and shale assigned to the Uinta Formation. These and the underlying marlstones of the Green River Formation are the only units of importance for this study.

In the Sand Wash "A" block where the shaft has been located, the average strike of bedrock at the surface is N75°E, and the dip varies between one and five degrees to the northwest.

Jointing is best expressed in the sandstone beds although the shales probably are also jointed. A photogeologic study of the area identified over 1200 joints. The primary set includes 23.4% striking N 60° 80° W and 29.9% striking N10 to 40°E (Figure 2). No evidence of faults was observed on the photographs in the area around the shaft site area. One 6 to 12-inch gilsonite vein has been traced on the surface in the vicinity. It trends N50°W, and can be followed for at least 2200 feet from the southeast to a point about 800 feet due south of the corehole location. Other small veins may exist in the area but have not been observed.

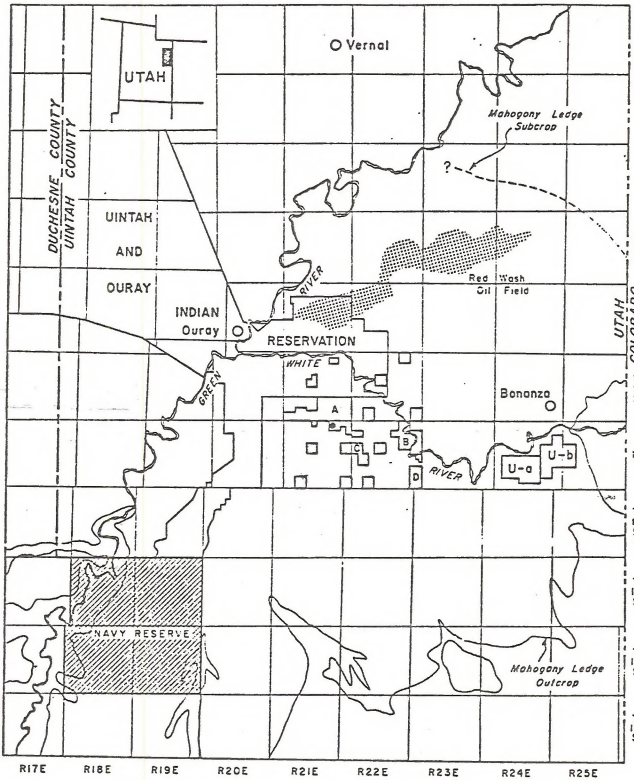
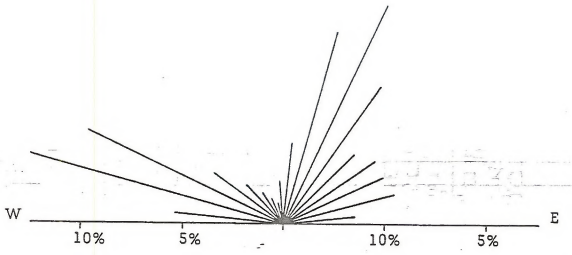


FIGURE 1

EASTERN UINTA BASIN

SHOWING TOSCO'S UTAH STATE
OIL SHALE LEASES



PERCENTAGE FREQUENCY OF STRIKES
1212 JOINTS; SAND WASH AREA

FIGURE 2

The topography of the area reflects the desert climate. It consists of flat-topped mesas capped by resistant channel sandstones and separated by broad valleys in the less resistant silt and shale. Relief is generally on the order of 50 to 100 feet. Drainage channels between the uplands are variously broad and alluviated or deeply incised. They are normally dry, but carry large flows during snow melt and after storms.

The climate in the area is semi-arid to arid. Precipitation averages 6 to 8 inches per year, partly as snow and partly as summer storms. Mean air temperature is 45° to 47° F and exhibits wide diurnal variation. The frost free season lasts 115 to 125 days.

3.3 SHAFT GEOLOGY FROM COREHOLE

Corehole Utah State 13X-2, in Section 2, T.10 S., R.21 E., Uintah county, Utah, was drilled by Tosco Corporation as a pilot hole for an experimental mine shaft. A detailed topographic map of the corehole site is shown in Figure 3, located in the map pocket The primary purpose of this hole was to obtain core for lithologic and rock properties evaluation of the Uinta and Green River formations. Secondary purposes included monitoring of gas, hydrology, and drilling conditions at the shaft site.

The hole was drilled and reamed with tricone bits to 120 feet, cored continuously to 2193 feet (40 feet below the mine zone), then drilled to 2380 feet total depth to provide geophysical logs of the deeper zones in the Green River Formation. The core was examined in detail at the drill site and a log prepared recording lithology, rock properties, hydrology, and drilling data. Because of the length of the detailed field log, a

reduced-scale log was prepared. In addition, the entire core was photographed in color as soon after recovery as possible to provide a permanent record. The core is retained in storage in Vernal, Utah for future examination.

Logs contained in Appendix A include a summary core log compiled at one inch equals five feet and a geophysical log. Descriptions of marker beds, fracture and parting classes, fracture spacing, fracture character, infillings and coatings, and RQD are included in the core log heading. A summary of the corehole is presented in Table 2.

3.3.1 Stratigraphy and Lithology

Three major lithologic zones of interest can be defined: (1) Uinta Formation; (2) Transition Zone; and (3) Green River Formation.

Table 3 shows the marker beds and lithologic zones identified in Utah State 13X-2 based on lithology of the cores and characteristics of the geophysical logs.

= shaft pilot hole ? (p.4)

Uinta Formation

From surface to 1000 feet, the Uinta Formation is predominantly siltstone and sandstone with minor amounts of shale and marlstone. The siltstones, which make up 49% of the section, are light- to medium-grey in color, variably argillaceous to very fine-grained, more or less calcareous, occasionally micaceous, and uniformly hard and competent. Bedding is mostly indistinct; occasional shaly partings are the most noticeable features. Contacts with other rock types are usually gradational.

TABLE 2

Summary of Corehole Utah State 13X-2

1.	Operator:	Tosco Corporation
2.	Location:	NW/4 SW/4 Sec.2, T.10 S., R.21 E., SLBM, Unitah County, Utah
3.	Elevation:	5064 GL., 5073 KB
4.	Contractor:	Carmack Drilling Co. Grand Junction, Colorado Rig #10, National 300-B
5.	Supervisor:	J. L. Moyer, Tosco
	Geologists:	J. Hartley, J. Hines, Amuedo & Ivey
6.	Spud Date:	22 October 1977
7.	Casing:	106 feet, 10-3/4", 45#, used casing, set with 90 sx class G plus 2% CaC_2
8.	Bit Size:	9-7/8" Tricone: 0' - 120' 15" Reamer: 0' - 106' 6-3/4" x 3-1/2" Diamond: 120' - 2193-2380 6-3/4" Tricone: 2193-2380
9.	Drilling Fluid:	Air Mist: 120' - 1769' Aerated Water: 1769' - 2380'
10.	Logs:	Lithologic 120' - 2193 Dual Induction: 106' - 2373' Simultaneous Density: 106' - 2373' Temperature: 316' - 2376' Hole Survey: 100' - 2373'
11.	Total Depth:	2380' Driller, 2376' Logger
12.	Completion Date:	15 November 1977

Table 3

Marker Beds and Lithologic Zones
Utah State 13X-2

	Log Depth	Datum
Uinta Formation	Surface	+5064
Top of Core	120'	+4953
Green River Formation	1348'	+3725
Top Mineralized Zone	1406	+3667
Upper Bird's-nest Zone	1524' 1569'	+3549 +3504
Lower Bird's-nest Zone	1625'	+3448
Base Mineralized Zone	1800'	+3273
Base Stillwater Zone	1922'	+3151
Four Senators Zone	1942' 1968'	+3131 +3105
Top "A" Groove	2077'	+2996
Top Mahogany Zone	2091'	+2982
Mahogany Marker	2113'	+2960
Mine Zone	2117' 2150'	+2956 +2923
Top "B" Groove	2180'	+2893
Core TD	2193'	+2880
Top R-6 Zone	2264'	+2809
Total Depth	2380'	+2693

The sandstones, comprising 37% of the interval above 1000 feet, range from light- to medium-grey, are mostly very fine- to fine-grained and silty, occasionally medium-grained, and generally well sorted with uniform texture. They are predominantly well-cemented, hard, and competent, ranging from slightly to highly calcareous. A few sand intervals were less well cemented and tended to be somewhat friable. Porosity and permeability are mostly very low. Bedding is poorly defined.

Shale and very minor marlstone make up the remaining 14% of this interval. The shales are various shades of green, brown, and darker grey, mostly argillaceous, though occasionally calcareous, and tend to break up as they dry.

Transition Zone

Between 1000 and 1348 feet, marlstone and oil shale become a major constituent interbedded with sandstones and some siltstones similar to those described above. The marlstone comprises 45% of the interval. It is light grey and barren in the upper part, becoming increasingly brown and kerogenaceous downwards, grading to low-grade oil shale between 1212 and 1250 feet. The interval from 1250 to 1350 is predominantly sand and silt. All of the rock in this zone is hard and competent.

Green River Formation

The top of definite Green River oil shale is at 1348 feet. The interval from this depth to core TD at 2193 feet is comprised of oil shale and marlstone, with

minor tuff beds and disseminated saline minerals. The oil shale is largely medium-brown in color and of relatively low kerogen content. Bedding is even to massive. A number of thin, dark-brown, rich streaks interrupt the sequence. The rock is predominantly very hard and competent.

The mineralized zone between 1406 and 1800 feet contains moderate amounts of nahcolite, calcite (?), and other saline minerals occurring in pods, rosettes, thin beds, coarsely fractured breccia zones, and in fine crystals disseminated through the oil shale. In most of the interval the nahcolite is fresh and unleached. However, leached vugs up to three inches across are found in two zones, each about 4 to 5 feet thick, at 1524 feet and 1560 feet. Substantial flows of poor quality water came from each of these zones, which are sections of the upper Bird's-nest aquifer. The Lower Bird's-nest zone contains both unleached nahcolite and a few leached, open vugs.

The Mahogany Zone in this corehole is comparable to that found in other holes in the area. The "A" Groove is 14 feet thick and composed of thin-bedded, platy, low-grade marlstone. The rich part of the Mahogany Zone is 89 feet thick. It is composed of dark-brown to black, even- to loop-bedded, rich oil shale zones, alternating with light- to medium-brown, even-bedded to massive, marly, leaner intervals. The "B" Groove, 84 feet thick, consists of grey- brown, marly, very low grade oil shale and marlstone.

The lower part of "B" Groove and the R-6 zone were not cored. However, based on density log correlations it is anticipated that the rocks here will be essentially the same as in Utah State #1. This section consists of beds of rich oil shale interspersed in generally lean marlstone

3.3.2 Structural Geology: Partings and Joints

Natural breaks were classed as partings if they occurred on planes of weakness parallel to the sedimentary bedding, or as joints if they crossed the bedding at any angle. The angle of dip of bedding and joints is measured downward from a plane normal to the core axis.

Bedding, with a few localized exceptions, was essentially normal to the core axis. Dips of 10 to 15 degrees were observed, but these occurred in short intervals and probably reflect post-depositional slumping or possible cross-bedding.

A deviation survey showed that the hole was slanted generally southeastward primarily at inclinations between 0.5 and 1.5 degrees from vertical. Therefore, the formations in the corehole area dip 0.5 to 1.5 degrees northwesterly.

Natural partings occurred with spacings that varied from less than one inch to several tens of feet. Mechanical breaks and partings were the most common breaks found in the Uinta Formation (120 to 1000 feet). In the upper 700 feet or so, most breaks probably were mechanically induced. However, they tended to be more

frequent in certain intervals and it is possible that in these zones the rock is somewhat weaker. Separations along bedding planes were predominant in the Green River Formation. As in the Uinta Formation most of these breaks were widely spaced, with zones of closer spacing usually occurring in lower grade oil shale or marlstone, which tend to be more brittle.

The mine interval will probably extend from a natural parting at 2121.2 feet to the base of the richer shale at 2154 feet. True depths of these horizons, as determined from the density log, are 2117 and 2150 feet.

There are four bedding-plane partings in the 10-foot section above the roof parting. Two are associated with the Mahogany Marker at 2117.5 feet, one is at 2115 feet, and the fourth is at 2111.5 feet. There was only one parting noted in the rib zone at 2144 feet. A few short, vertical joints were noted at 2124 and 2145 feet. These were only an inch or two long and not broken in coring. Except for these discontinuities, the rock is hard, unweathered, and of excellent quality throughout the rib and roofstone section.

Only 65 joints were logged in the entire cored interval. Of this total, 41 joints were vertical or nearly so, 18 dipped between 55 and 80 degrees, and six were between 25 and 50 degrees. Over half of the observed joints were logged as sealed or recemented. Most were only a few inches to a foot in length with the longest extending for about 5 feet.

what & where?

As in the core from the Utah State #1, very few of the joints or partings logged in 13X-2 contained mineral coatings or showed evidence of weathering. However, high pour-point, asphaltic crude oil was commonly present in open joints and partings. Plates 1 to 8 show typical core with partings and joints from various sections throughout the corehole.

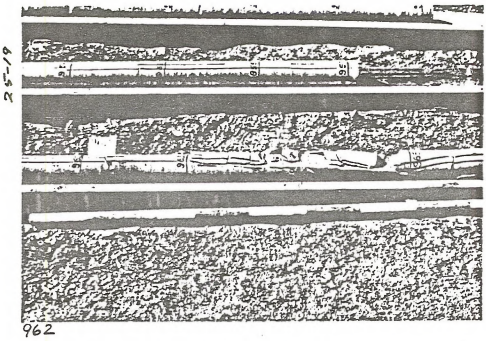


Plate 1. Vertical Open Joint in Siltstone.

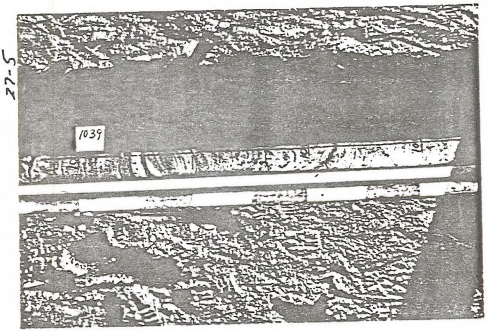


Plate 2. Contorted Bedding Plane Partings in Sandstone, Drilling Induced.

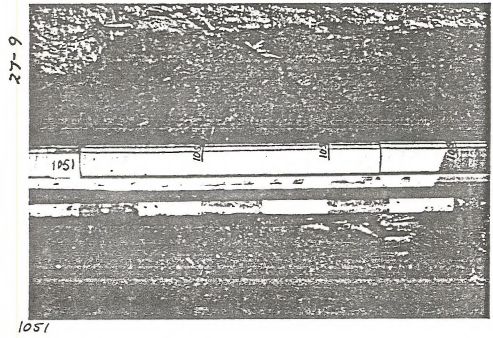


Plate 3. Hard Marlstone Natural Parting at 1053.3 Feet.

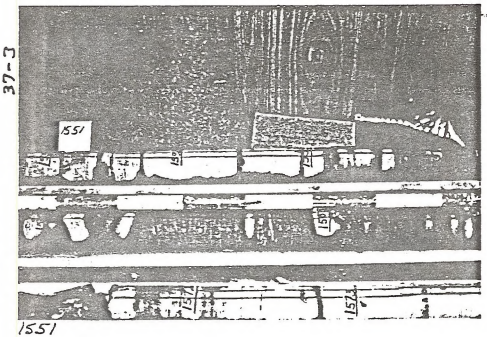


Plate 4. Vertical Open Joint, 1553 to 1554 Feet, Extends up to 1551 Feet.

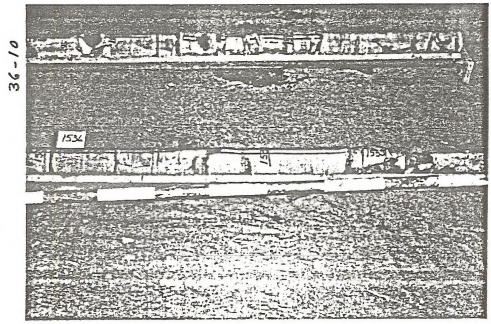


Plate 5. Calcite Crystals on Fracture Surface, 1536 to 1537 Feet.

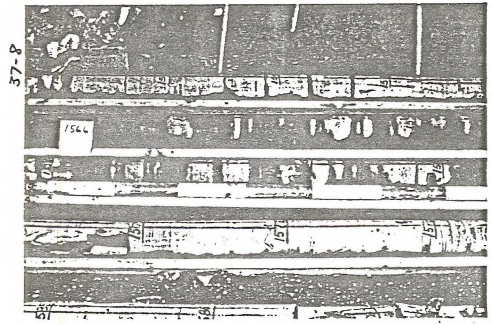


Plate 6. Short Vertical Fracture, Part of Aquifer.

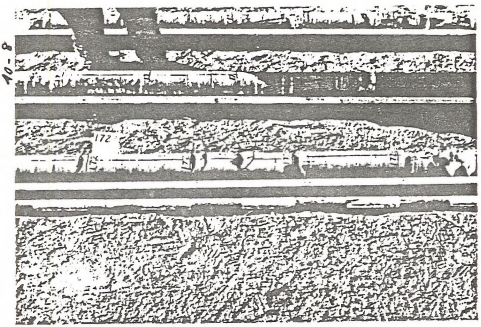


Plate 7. Slanted Fractures in Hard Oil Shale.

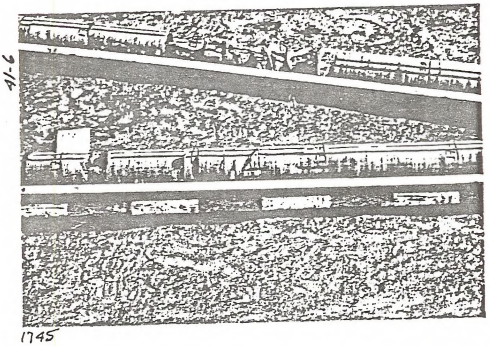


Plate 8. Slanted Fractures in Hard Horizontally Bedded Oil Shale.

5.0 HYDROLOGY

It was intended that the entire hole be drilled with air mist so that hydrologic parameters could be logged throughout. However, problems of impoundment of excessive quantities of poor quality water necessitated converting to aerated water to reduce volumes and avoid lost circulation difficulties. The mist injection rate varied between 7 and 14 gallons per minute (gpm).

5.1 AQUIFER ZONES

During drilling of the interval above 1525 feet the measured return flows were essentially equal to the injected quantities. This indicates that there were no aquifer zones penetrated in the Uinta Formation at this location. However, a low volume sandstone aquifer was encountered in Utah State #1 and high flows have been reported from the formation in the general area. It appears that the water bearing rocks are lenticular, channel-sand bodies which should be randomly distributed. The absence of water in this interval in 13X-2 would not ensure against encountering water within relatively short lateral distances.

A marked increase in water production occurred at 1529 feet, about 180 feet below the top of the Green River Formation. Measured flow quickly increased to a net 276 gpm and was stable at 300 gpm on a jet test made about

12 hours later. A strong odor of hydrogen sulphide accompanied the water inflow and persisted throughout the succeeding 10 days of drilling.

An abrupt increase in injection back pressure from 450 to 750 psi was observed while drilling at 1568 feet. Water production jumped to over 500 gpm and was at 567 gpm and increasing when the last measurement was made prior to converting to aerated water.

The two water-bearing intervals are at the top and base of the Upper Bird's-nest aquifer zone. Based on the core, the first aquifer is five feet thick and comprises a zone of interconnected, leached-out, nahcolite cavities. Joints were not obvious in this zone. The second aquifer exhibited some leaching of small nahcolite pods and dissemenated crystals, but was primarily expressed by open vertical fractures between 1565 and 1574 feet.

Fresh, crystalline nahcolite was contained in the oil shale above and below both of these water bearing zones, suggesting that they may be laterally extensive but with restricted vertical water movement.

Water flows could not be measured after conversion to aerated water. There were no pressure surges indicative of increases. However, leached nahcolite cavities at 1652 feet and 1769 to 1775 feet indicate possible water zones in the Lower Bird's-nest aquifer.

5.2 JET PUMPING TEST

A jet pumping test was made at a depth of 1542 feet (14 feet below the upper aquifer). Water production was stable at 301 gpm during the pumping phase and a water sample was taken after 75 minutes of jetting. Measurement of recovery was hampered by foaming that made readings inaccurate at best. Transmissivity was calculated to be 246 g/d/ft. Static water level at the end of the test was at 240 feet, producing a hydrostatic head of 1285 feet or 556 psi at the aquifer depth.

In an effort to acquire drawdown data resulting from jet pumping, a Stevens water level recorder was kept in continuous operation on the Shell 14X-34 corehole, located approximately 6000 feet west-northwest of 13X-2. An estimated four million gallons of water were pumped from 13X-2 in two periods: three million gallons between November 4th and 12th, and one million gallons between November 13th and 15th. About 300,000 gallons were pumped back into the hole on the 12th and 13th of November. No effects of pumping or injecting water at 13X-2 were observed at 14X-34.